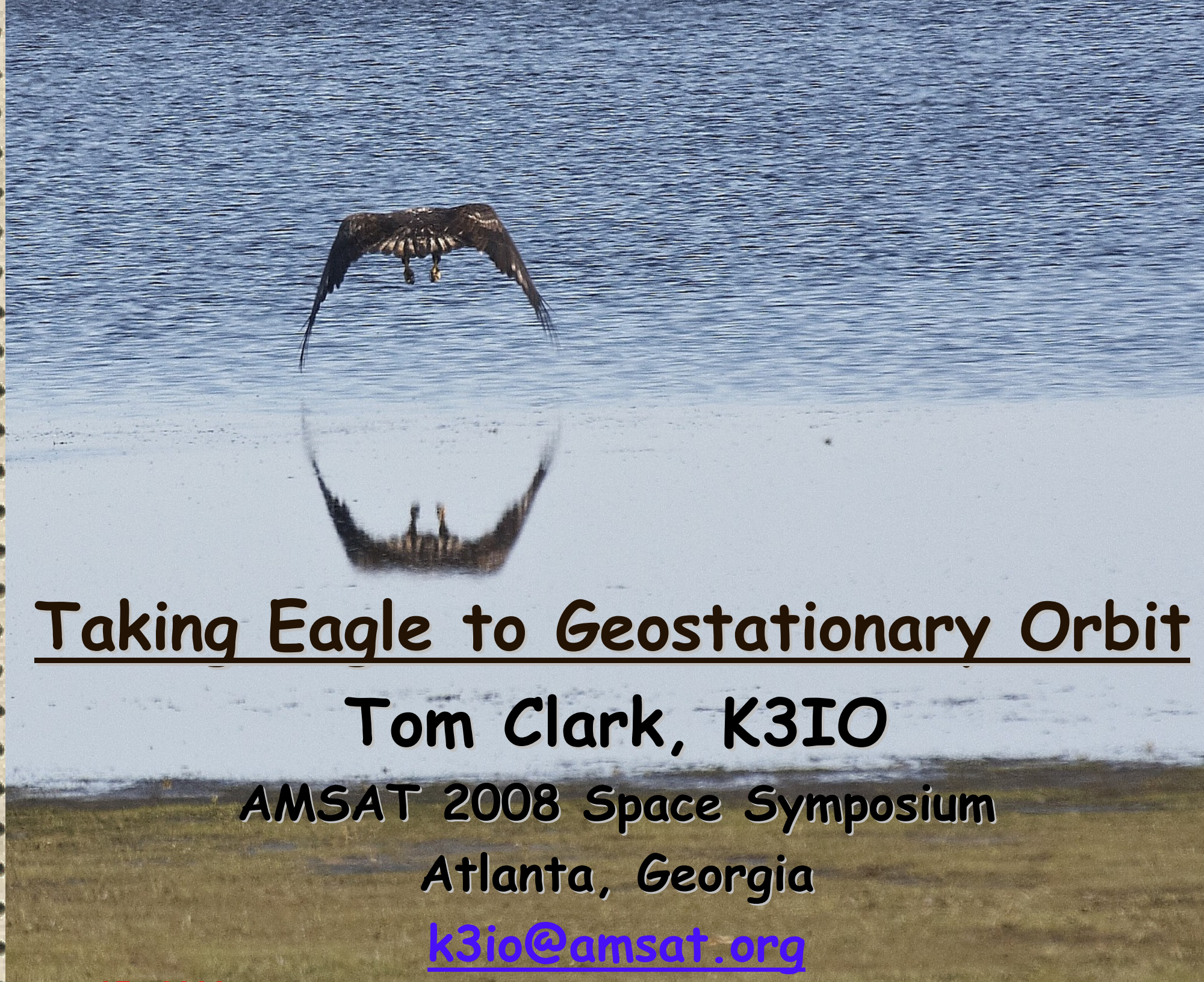

Taking Eagle to Geostationary Orbit

Tom Clark, K3IO

AMSAT 2008 Space Symposium

Atlanta, Georgia

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An Important Disclaimer

- The material I present in this talk represent my ***personal*** ideas and are not those of AMSAT-NA.
- These ideas have not been reviewed by AMSAT's Board of Directors, Officers, o the volunteers in the EAGLE project.
- This design was prepared as a strawman, test concept to see if an adaptation of EAGLE could be hung onto a commercial GEO mission.
- I have no idea whether or not AMSAT ca ever build or afford a GEO flight.

The only *guaranteed* option is *DOING NOTHING* – which offers the absolute guarantee that nothing will happen !

AMSAT's Mission & Vision (2004)

- AMSAT is a non-profit volunteer organization which designs, builds and operates experimental satellites and promotes space education. We work in partnership with government, industry, educational institutions and fellow amateur radio societies. We encourage technical and scientific innovation, and promote the training and development of skilled satellite and ground system designers and operators.

- **Our Vision is to deploy high earth orbit satellite systems that offer daily coverage by 2009 and continuous coverage by 2012.**
- AMSAT will continue active participation in human space missions and support a stream of LEO satellites developed in cooperation with the educational community and other amateur satellite groups.

24/7 by 2012! Are you crazy?

- When the vision statement was written in 2004, we planned on AMSAT-DL's P3E satellite flying by ~2007-8.
- AMSAT-NA supports AMSAT-DL in any way possible to achieve this goal.
- AMSAT-NA committed to the EAGLE project to develop new HEO satellites
- Both P3E & EAGLE depend on the availability of elliptical HEO launches (in particular, on GTO piggyback rides)

Meanwhile, Back to the Real World: P3E

(1)

There's No Such Thing as a Free Launch

- AMSAT-DL has had an amazing track record in obtaining piggyback Arianne launches.
- Karl Meinzer, DJ4ZC is held in awe by the European space community (and amateurs!) for the low-cost technology developments embodied in P3A, AO-10, AO-13 & AO-40.
- Karl's lifetime dream has been P5A, an independent "amateu mission to Mars.
- Karl and AMSAT-DL plan that P3E is a test-bed for P5A.
- But under German rules, Karl had to retire in 2006.
- In retirement, Karl's resources (especially the lab in the University of Marburg's ZEL) have dried up.
- **Although the P3E hardware is nearly done, AMSAT-DL has been unable to secure a launcl**

Meanwhile, Back to the Real World (2)

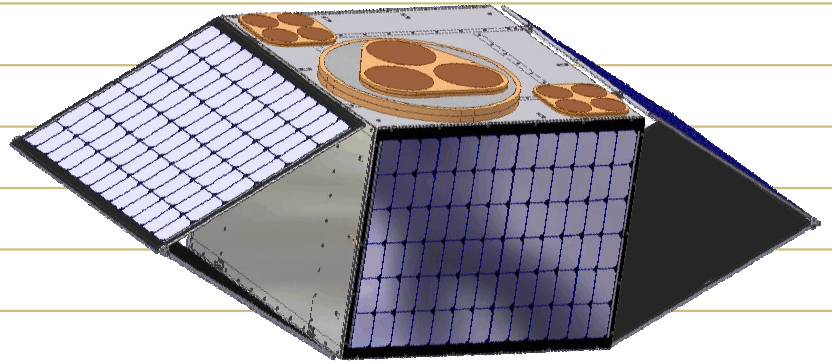
There's No Such Thing as a Free Launch !

- Over on this side of the pond, **AMSAT-NA** has be beating the bushes for suitable GTO launches. Lee McLamb (KU4OS) has attended countless ***"Smallsa*** and ***"Rideshare"*** meetings.
- **Suitable GTO launches are few and far betwee**
- Co$t foreca$t$ range from $2M-$10M (M=10^6).
  - Needless to say, this number exceeds the threshold of pai for an amateur project.
- Even LEO satellites are costing more real money.
  - Russian launches have cost ~$20k/kg, but costs are ⬆⬆⬆
  - Russians launches are getting tougher and tougher as the usable SS-18/-19s (+ technicians that can light the fuses) a being depleted.

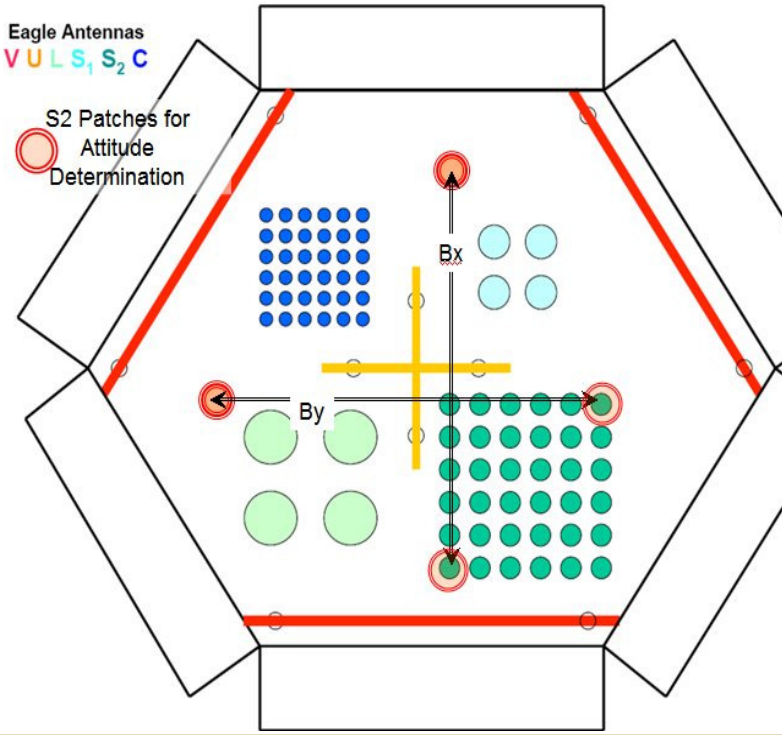
The Original EAGLE Project (1)

- EAGLE evolved as concept design for a relatively simple HEO satellite in an elliptical orbit, followin DJ4ZC's design for P3A & AO-10/13 & P3E.

- The initial "strawman" EAGLE design looked something like this:



- This led to the evolution of a flatter, more symmetric 6-sided EAGLE. This sketch ("top" view) shows a possible configuration of the phased array antennas that I was designing.



The Original EAGLE Project

(2)

Like all P3 satellites, EAGLE requires many subsystem

1. All the RF hardware that we think of as amateu radio, including phased array antennas,
2. An apogee kick motor (with all the associated fuel tanks, plumbing, valves, etc),
3. Attitude determination hardware to figure out which way the satellite is pointing (needed to f the kick motor and to point the antennas),
4. Magnetic Torque hardware (to spin & point the satellite while it passes thru perigee),
5. Solar panels & batteries & power conditioning hardware (100 watts or more, orbit average),
6. And a real-time, multi-tasking control computer to make all these widgets play together.

Not Really Amateur Radio !

GEO -- the new HEO idea

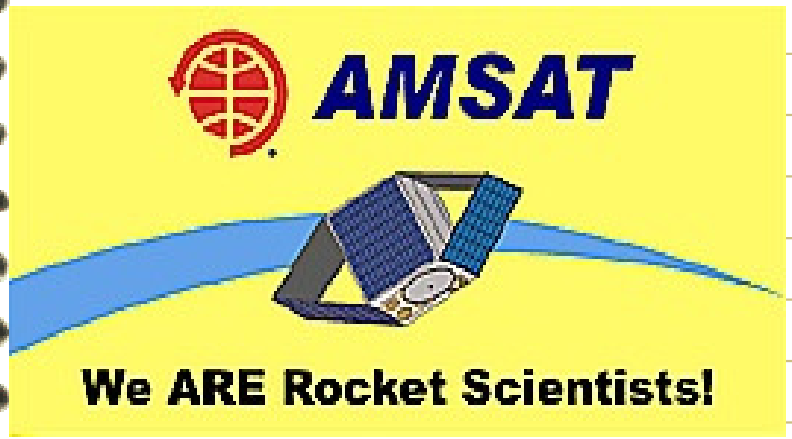
While attending "Smallsat" and *"Rideshare"* meetings, KU4OS learned of the possibility of an amateur packages attached to commercial GEO-stationary satellites at a competitive price.

All of a sudden, the lightbulb lit very brightly !

If we hitchhike a ride to GEO, it would mean that:

- **RF & Digital hardware is all we have to supply,**
- No kick motor is needed,
- They supply attitude control, nadir pointing to 1-2
- They supply hundreds of watts of power.
- We can have a satellite with 24/7 coverage of North & South America & much of the Pacific.
- Oh yes (don't forget) -- **No kick motor is needed**

Oh yes (and don't forget)
No kick motor is needed !



It hurts me to say it, but AMSAT has had bad luck with kick motors.

Especially with AO-40

IMHO: I would just as soon let the "pros" handle our pyrotechnic displays.

Also of interest ☺ :

- **IF** we don't blow this opportunity,
- **AND IF** we can figure out how to afford the rides,
- **THEN** this launch opportunity looks like a renewable resource
- **ELSE** I have no fresh ideas on where to find a launch ☹ ☹
- **ENDIF**

Some System Design Considerations

- We want to use as many concepts developed for EAGLE as possible, but we have a clean slate for many of the details.
- Our **GEO** host is designed for 10-20 year lifetime, and so must we. Therefore we should design for amateur radio circa 2020
- **IMHO**, **Finally** this gives us a real need to justify & defend our valuable microwave allocations with a real, long lived operationa system.
- Folks with serious CC&R antenna limitations can use "stealthy" fixed small dishes.

My ideas are based on the premise that all future satellites will concentrate on microwave frequencies

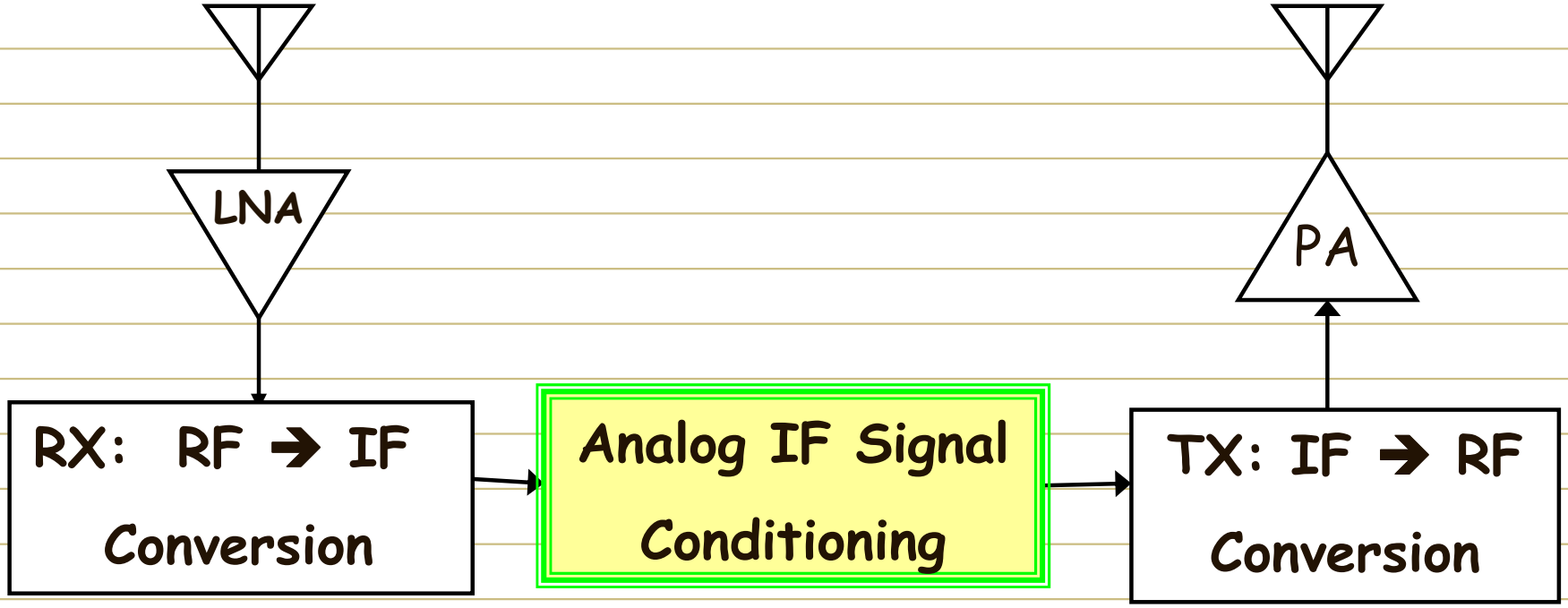
United States Microwave Allocations			
Amateur Service in the USA		**Amateur-Satellite Service**	
Band (λ: MHz)	**Bandwidth (MHz)**	**Band (MHz)**	**Bandwidth (MHz)**
23 cm: 1240-1300	60	1260-1270 ↑	10
13 cm: 2300-2310 13 cm: 2390-2450	10 60	2400-2450	50
9 cm: 3300-3500	200	3400-3410 Θ	10
5 cm: 5650-5925	275	5650-5670 ↑	20
		5830-5850 ↓	20
3 cm: 10000-10500	500	10450-10500	50
1.3 cm: 24000-24250	250	24000-24050	50

↑ means Earth-to-Space (uplink) direction only

↓ means Space-to-Earth (downlink) direction only

Θ the 9 cm satellite band is only available in regions 2 & 3

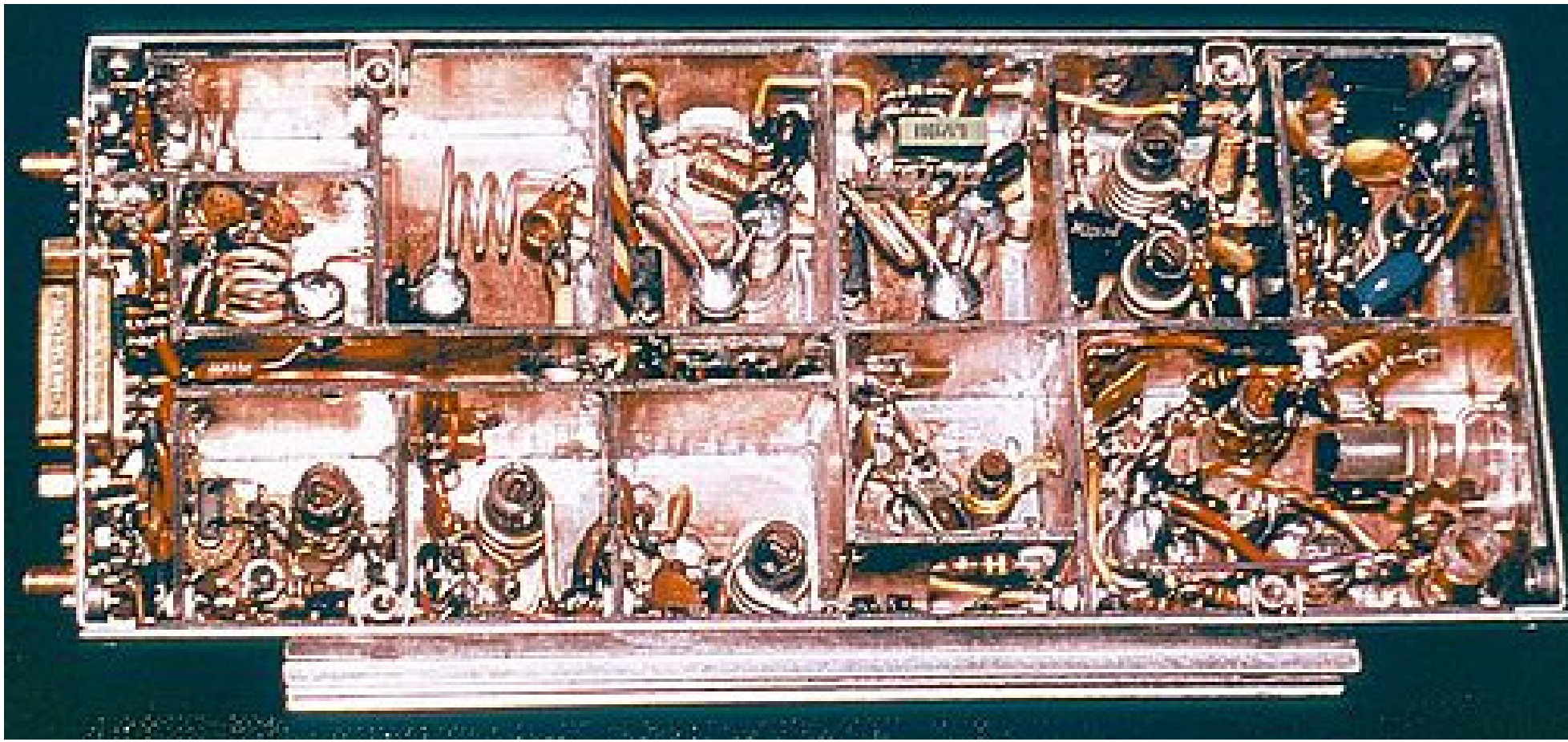
"Old" Spacecraft used simple "Bent Pipe" Linear Transponders:



- A major design issue: DC-to-RF conversion efficien
Every watt of power in space is a precious commodit

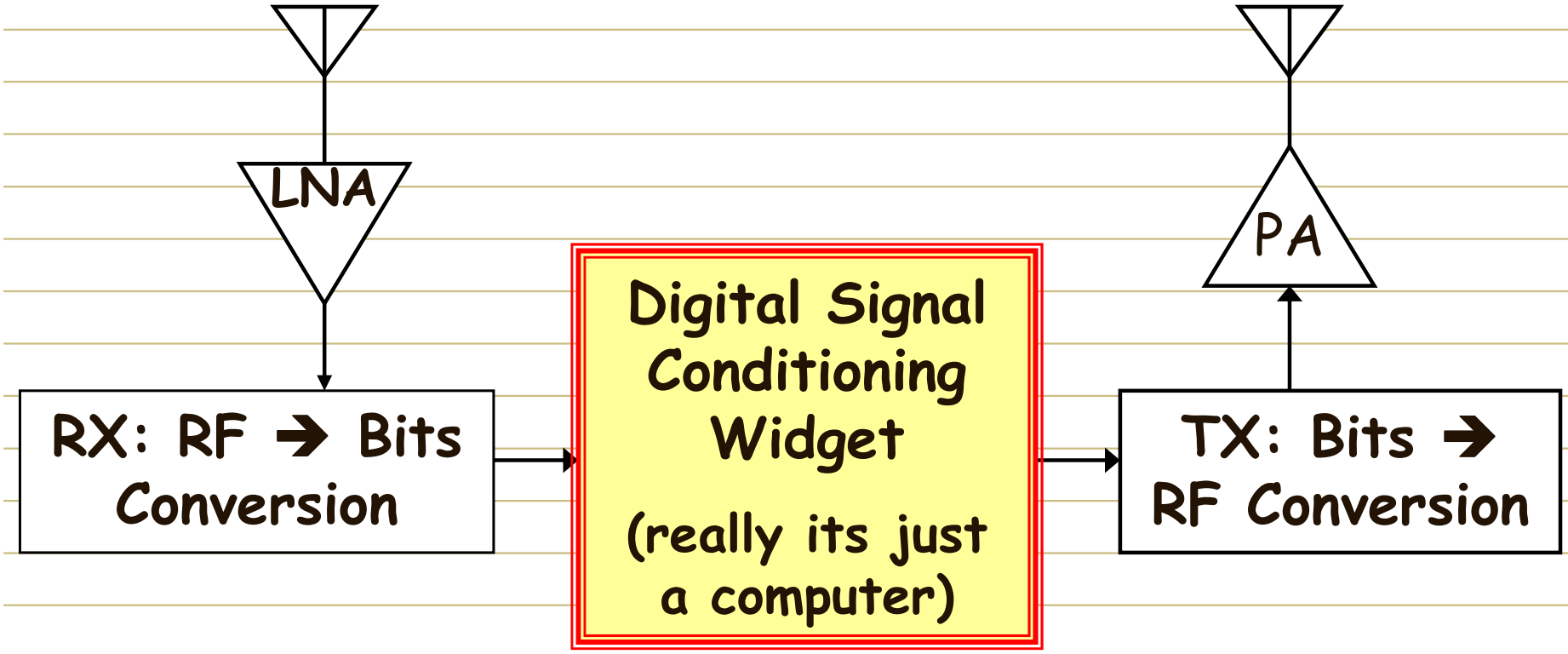
- A secondary issue is dynamic range. Previous satelli
transponders (like AO-7 Mode-B) have been plagued
with a lot of user-to-user intermod; the noise floor
has been as poor as -26 dB below peak.

An "old" Transponder: AO-7's Mode B



This transponder achieved high DC -> RF efficiency by using DJ4ZC's "**HELAPS**" technique, but with ~26 dB dynamic range.

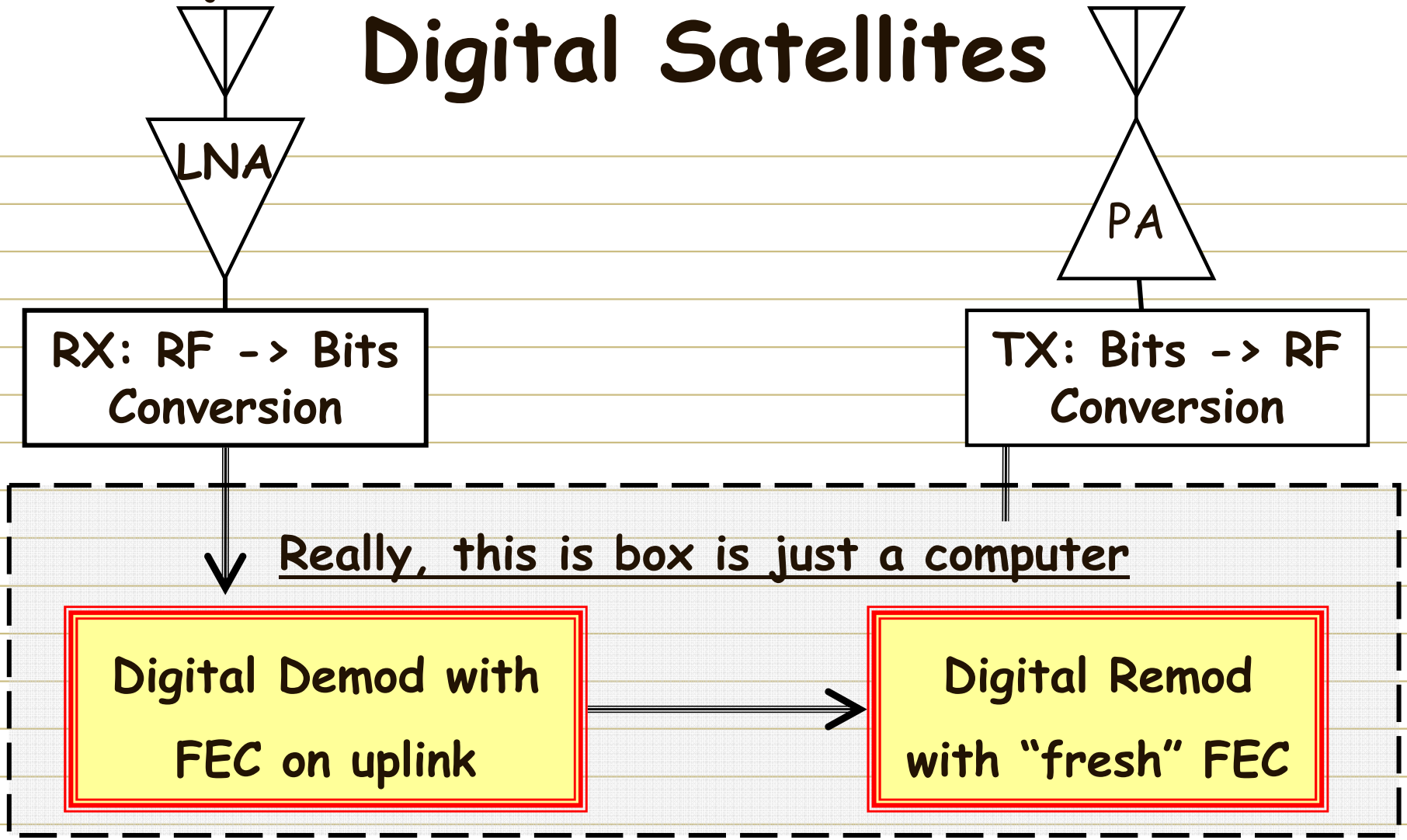
The "New" Software Defined Linear Transponder Concept **(SDX):**



Some of us have become convinced that we can do a much better job by doing <u>all</u> the signal conditioning tasks in DSP hardware.

(see G6LVB's talk)

Lately, we have talked a lot about Digital Satellites


LNA
PA
RX: RF -> Bits Conversion
TX: Bits -> RF Conversion
Really, this is box is just a computer
Digital Demod with FEC on uplink
Digital Remod with "fresh" FEC

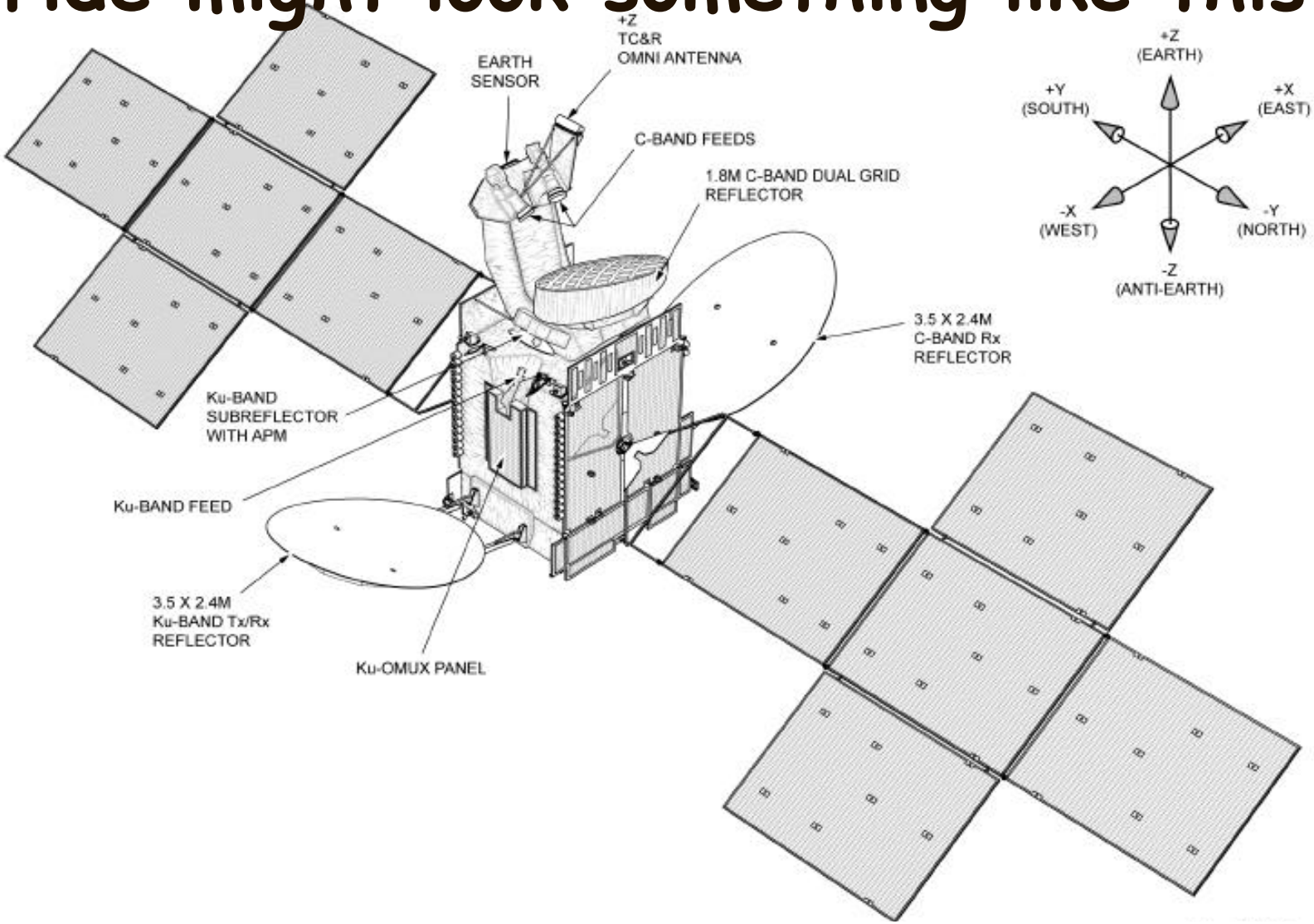
- If we use a "bent-pipe" linear transponder, then we lose uplin SNR ~$1/R^2$ & lose downlink SNR ~$1/R^2$, for a total loss ~$1/R^4$
- But with separate Demod/Remod (each with error correction) then the link SNR scales as a pair of ~$1/R^2$ links

Here is K3IO's initial "strawman" design for **GEO EAGLE** :

We **must** make maximum use of our microwave bands

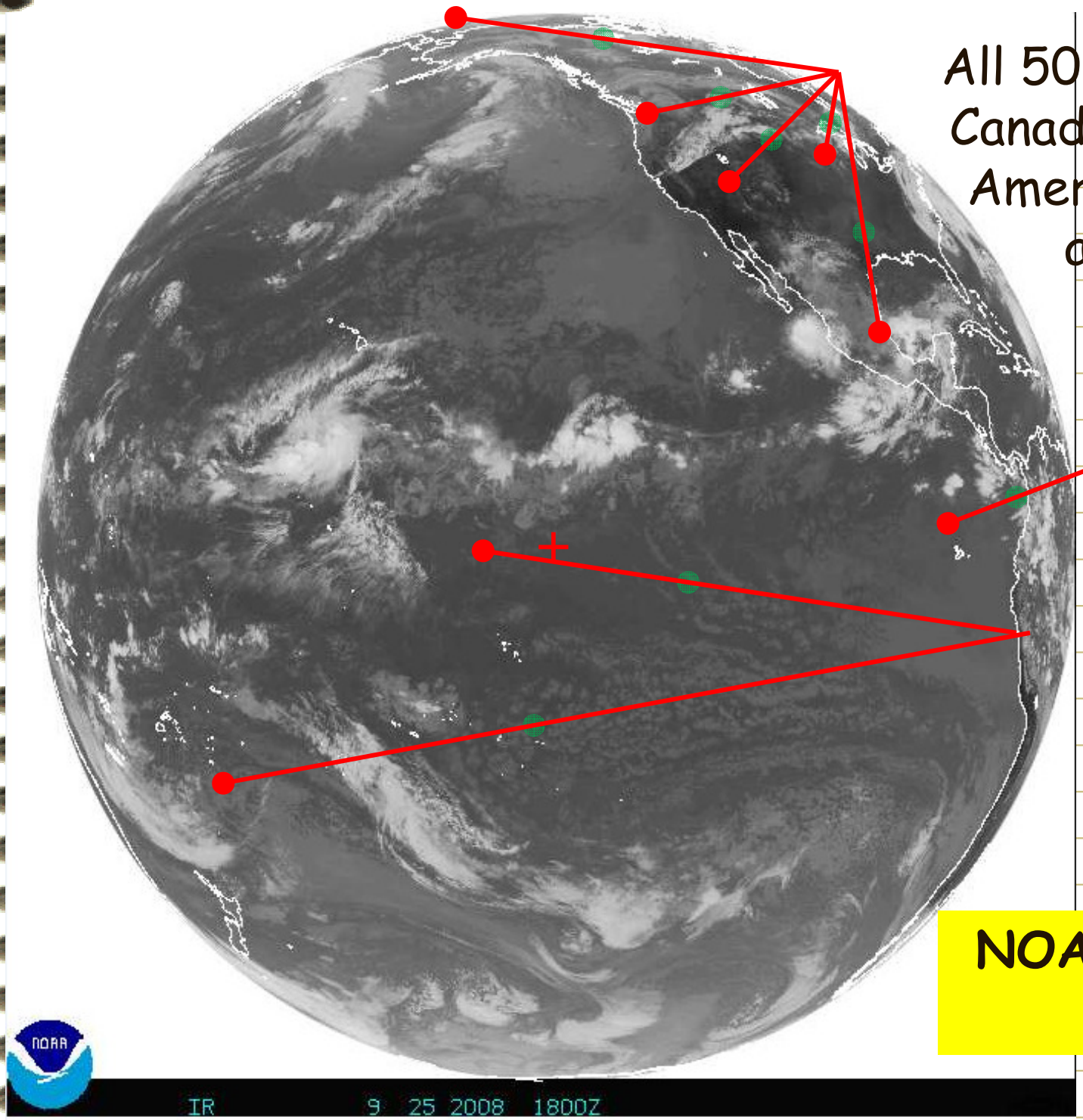
- 'They' use C-band (6+ GHz) uplinks, so we should us
  our C-band (5650-5670 MHz, λ=5 cm) uplink. ☺
  - This means our ground-based user's TX will help to prove w
    exist to the 802.11a, wireless phones and other unlicensed
    Part 5 users. ☺ ☺ ☺
- The best match for 'their' 4+ GHz downlink is our
  S2-band (3400-3410 MHz, λ=9 cm *ok in Region 2*) ☺
  - Space *may* permit us to also include S1-band (2400-2402 M
    λ=13 cm) for either uplink and/or downlink. ☺
  - Antenna space does not permit high gain antennas on V/U/L
    (λ=2m/70cm/23 cm). 'They' are concerned about possible R
    so any hardware on these bands will be receive only. Becaus
    antenna area is small, EME-class **QRO!** stations required ☹

We have been told that GEO-EAGLE's ride might look something like this



- It might fly in 2011, and it might be parked around **130° W**.
- 'They' have asked how we might fit a useful AMSAT payload into some areas they suggested, and asked for size & weight & power estimates.

Isn't ~130°W too far west to be very useful?



All 50 US states + most o
Canada + Mexico + Centra
America + the Caribbean
are in view 24/7

Most of South
America (except
Brazil)

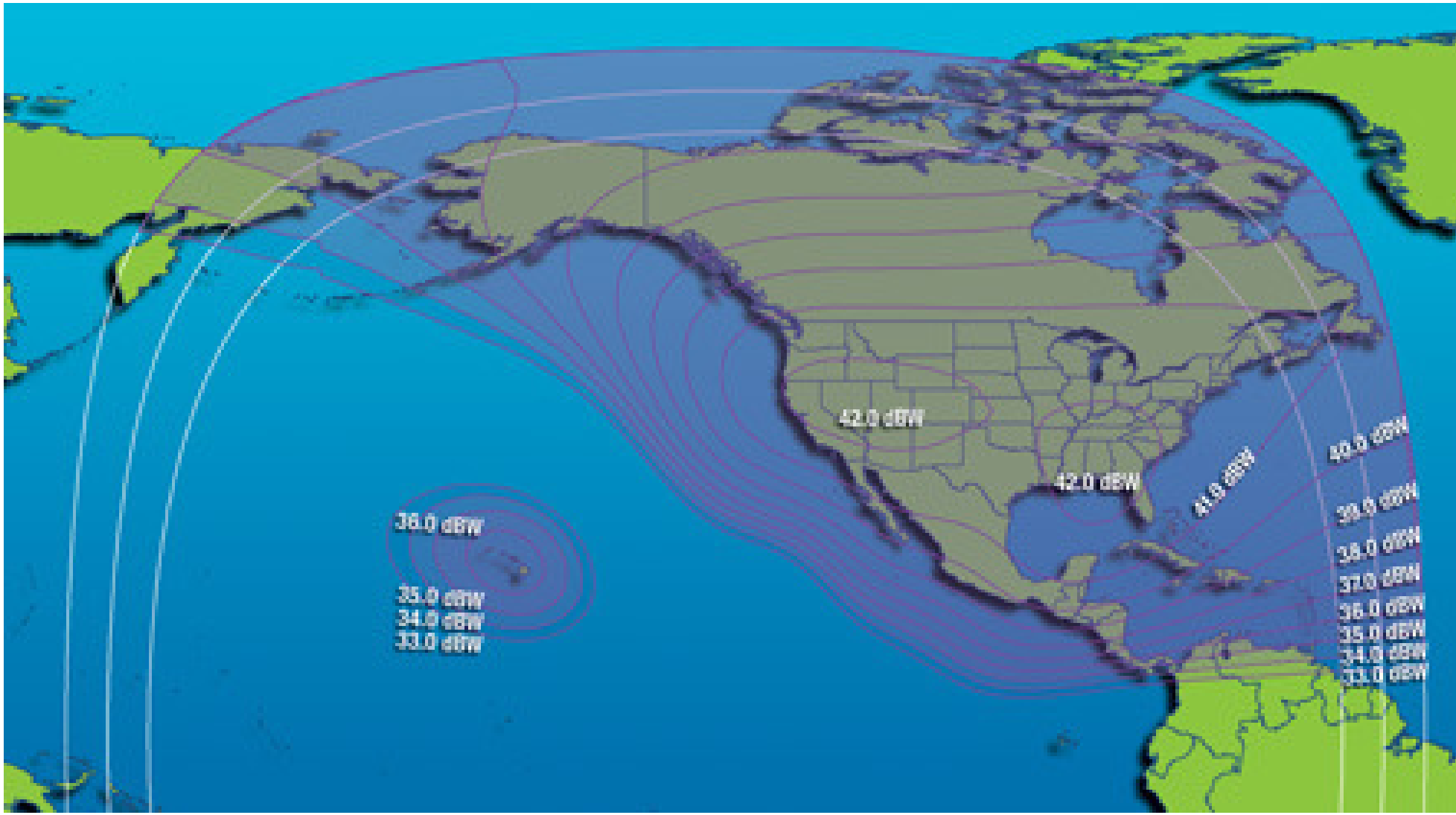
Most of the Pacif
Islands (& maybe
New Zealand)

NOAA's GOES WEST is at 130°W

Coverage Map for 129° W

Calculations courtesy Intelsat:

http://www.intelsat.com/resources/satellitedata-pas/look_calc.asp



Some Sample Elevation Angles

Boston= 14.7°	Quebec= 13.0°	Newfoundland= 0
Chicago= 26.3°	Anchorage= 18.5°	Auckland= 18.1°

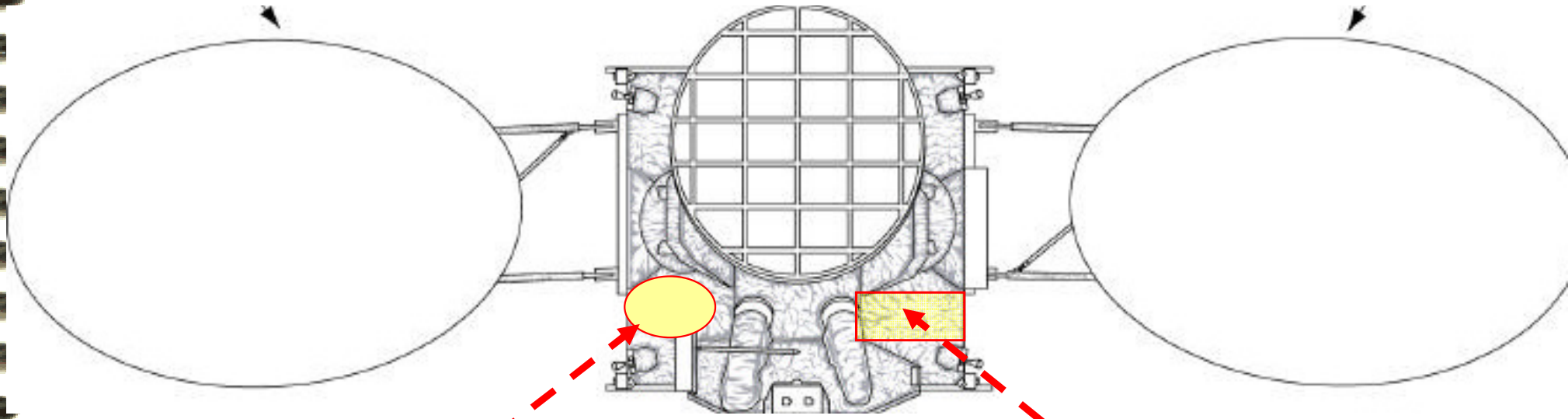
Now let's look at the K3IO's "strawman" GEO EAGLE payload design

Again, I offer a caveat emptor:

- The material I present in this talk represent my *personal* ideas and are no those of AMSAT-NA.
- These ideas have not been reviewed by AMSAT's Board of Directors, its Officers, or the volunteers in the EAGLE project.
- This is very much a work in progress.
- I have no idea whether or not AMSAT can ever build or afford a GEO flight.
- I reserve the right to change my mind

Especially if I have violated any fundamental Laws of Physics !

'They' Suggested Some Possible AMSAT Transponder Payload Locations



Possible Antenna Location (Clearest Eastern View)

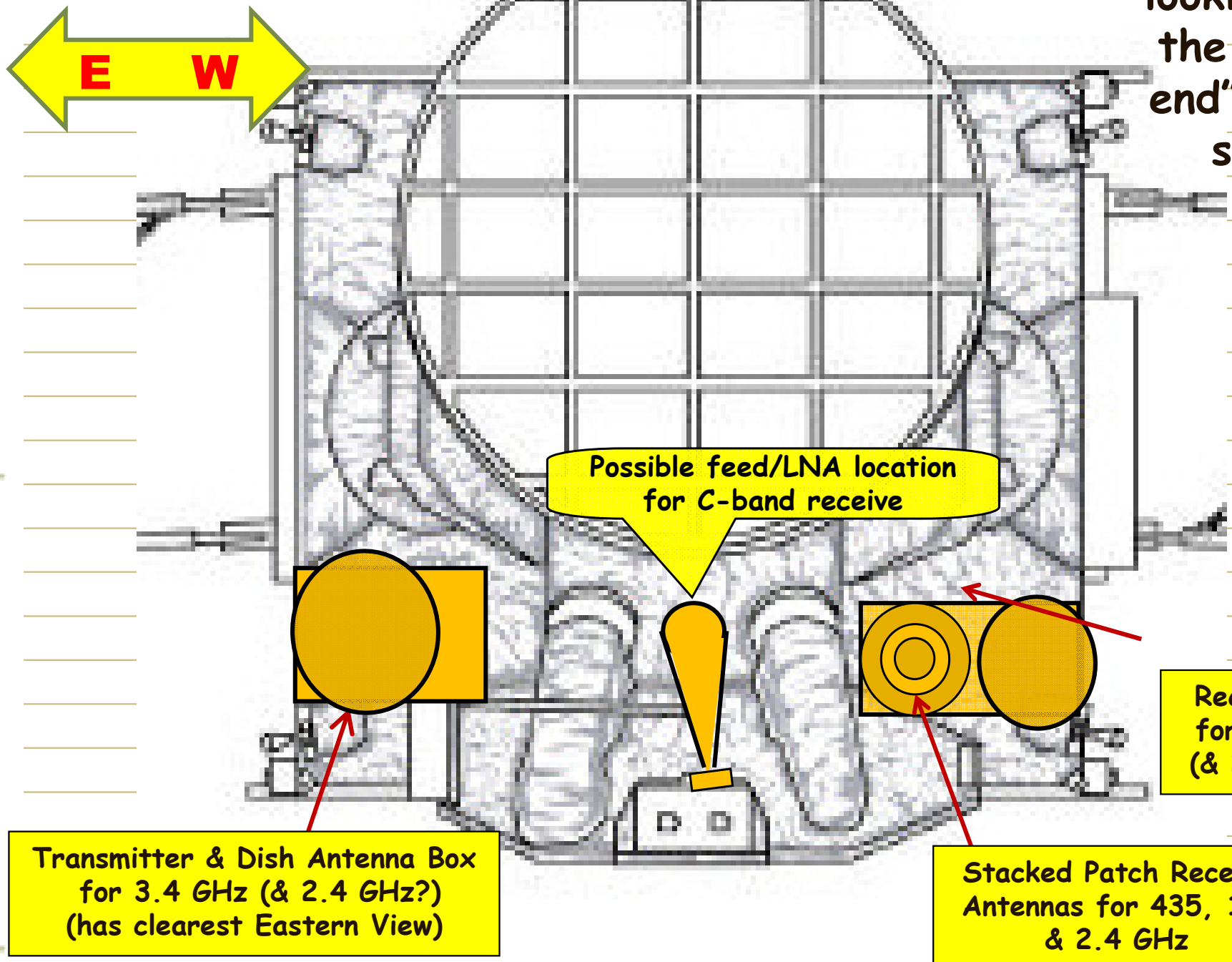
Possible Hardware Location

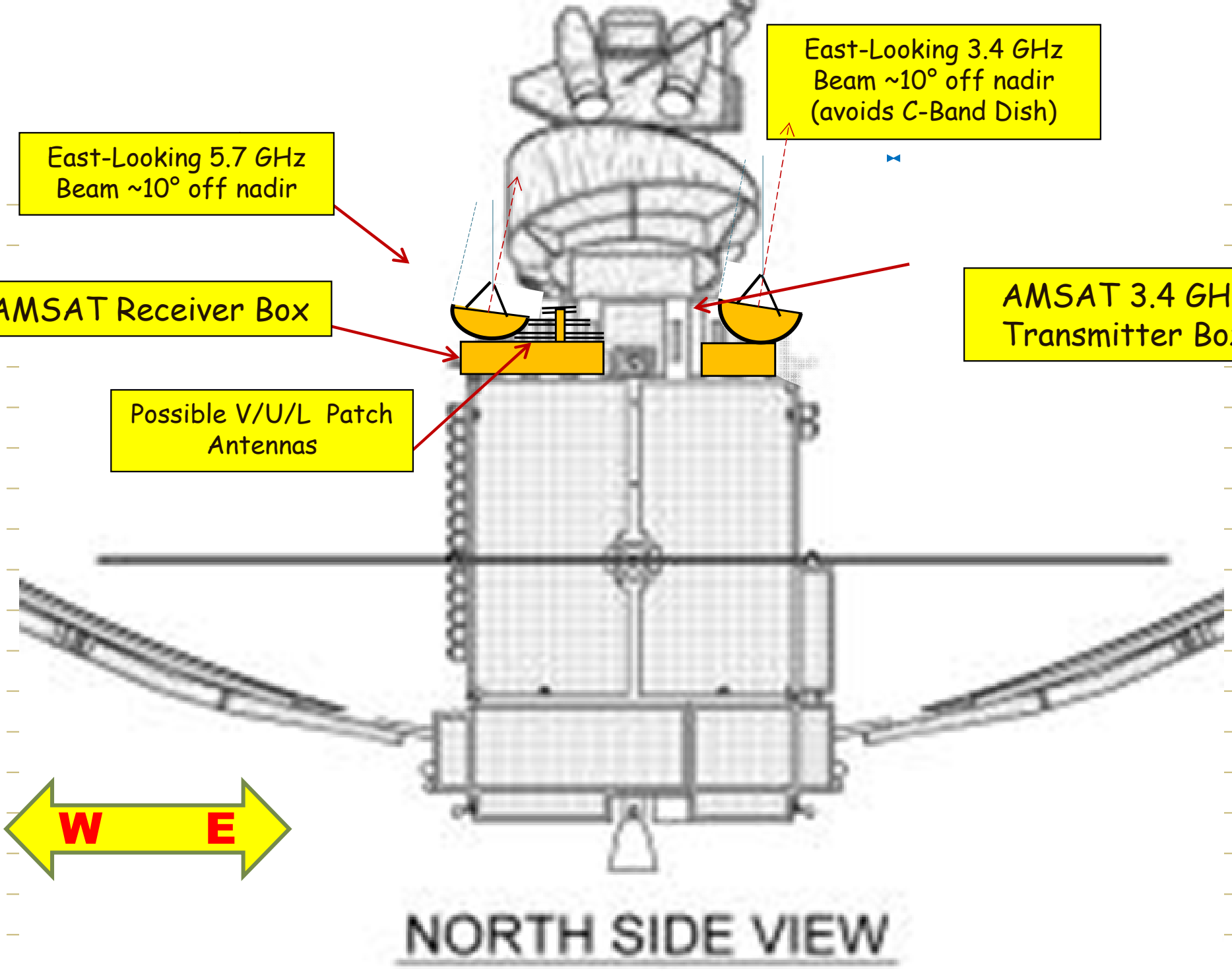
AMSAT's Primary Locations

per

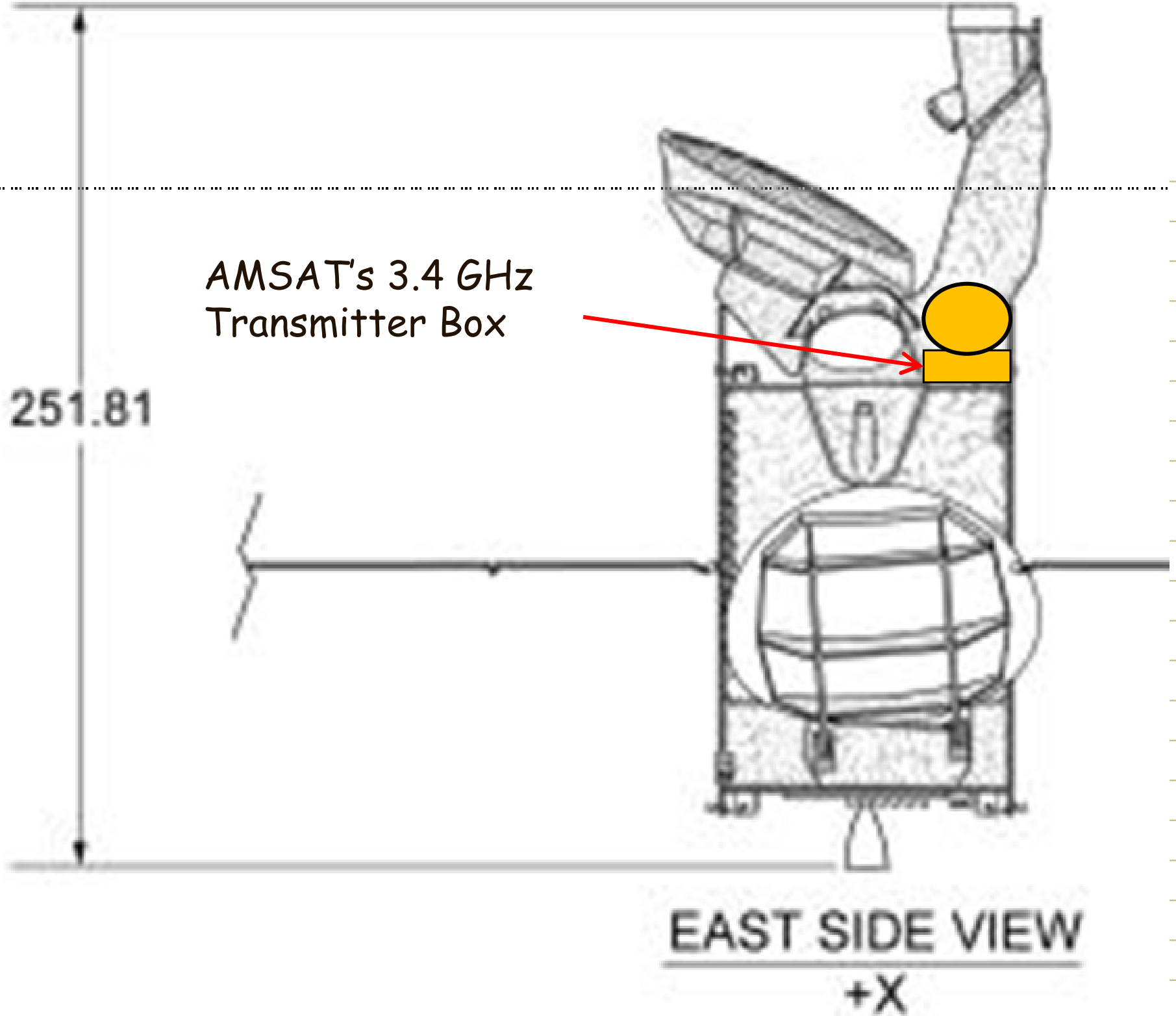
K3IO

View from Ear
looking "up" o
the "business
end" of 'thei
satellite


E W
Possible feed/LNA location for C-band receive
Receive Dish for 5.7 GHz (& 2.4 GHz?)
Transmitter & Dish Antenna Box for 3.4 GHz (& 2.4 GHz?) (has clearest Eastern View)
Stacked Patch Receive Antennas for 435, 1.3 & 2.4 GHz



(note: AMSAT Boxes are really on the South Side, but I only had North Side View)


AMSAT's 3.4 GHz
Transmitter Box
251.81
EAST SIDE VIEW
+X

Notes on Antennas for GEO EAGLE

- Examination of the sketches we were provided show that their ~2M "grid" dish may block coverage. Therefore, the TX dishes have been tilted ~10° East of nadir.
  - This improves the downlink signal for East coast users, at the possible cost of degrading coverage of New Zealand.
- Since 'they' provide a stable platform pointed at the Earth, dish antennas are chosen for the microwave bands.
  - From GEO altitude, the earth ~18.3° in size, corresponding to a antenna directivity ~22 dBi (independent of frequency).
  - From GEO distance, $1/R^2$ differences make nadir ~1.5 dB "hotter" than the limb (independent of frequency).
- 'They' have suggested our boxes be sized ~36-64 cm (14-25"
  - Dishes in the 36-64cm range are likely candidates, although th is a bit too small for the "***Dishes should be ≥ 8-10 λ in size***" criterion at λ=5,9 or 13 cm.
- Any V/U/L receive antennas are likely to be λ/2 diameter patches with only ~6dBi gain.

Now -- A Radical New Payload Idea

(1)

Since the universal "bent pipe", all mode, general purpose linear transponder (when implemented as an **SDX**) has guts that look like:

Digital Signal Conditioning Widget (really its just a computer)

And since a full digital bit-oriented system has guts like:

Really, this is box is just a computer

Digital Demod with FEC on uplink → **Digital Remod with "fresh" FEC**

☺ **Let's just fly a bunch of computers surrounded by some RF widgets.** ☺

A Radical New Payload Idea (2)

Starting with the 5.7 GHz receiver.

We have 20 MHz of bandwidth. Let's use all of i

- Use a single, high-speed A/D converter at convenient IF.
- Sample at ≥ 20 MHz (complex) or ≥ 40 MHz (real).
- 8-10 bits should be enough.

Down-sample & use a Polyphase Filter Bank (PFB) to split the entire band into N sub-bands.

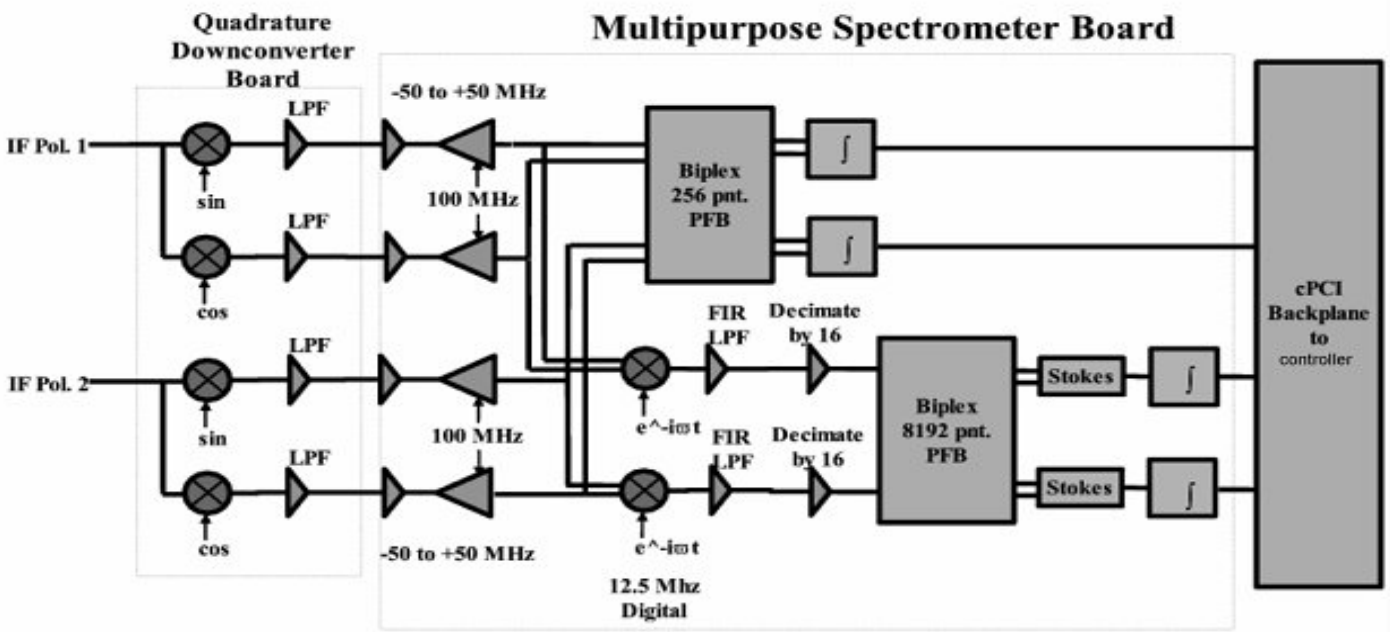
- Perhaps use N=32 bands, each 20/32=625 kHz wide)
- PFBs are best implemented in FPGAs with a lot of FIRs
- Some good/interesting FPGA/PFB references:

http://slaac.east.isi.edu/presentations/retreat_9909/polyphase.pdf
http://www.fpgajournal.com/whitepapers_2005/accelchip_20050915.htm
http://seti.berkeley.edu/galfa/signalproc/pfb.html
http://casper.berkeley.edu/McMahon-Thesis.pdf
http://ccrma.stanford.edu/~jos/sasp/Multirate_Filter_Banks.html
http://matlabdb.mathematik.unistuttgart.de/download.jsp?MC_ID=12&MP_ID=62
http://www.mathworks.com/products/filterdesign/demos.html?file=/products/de
/ shipping/filterdesign/iirallpassdemo.html

An application of a FPGA-based PF

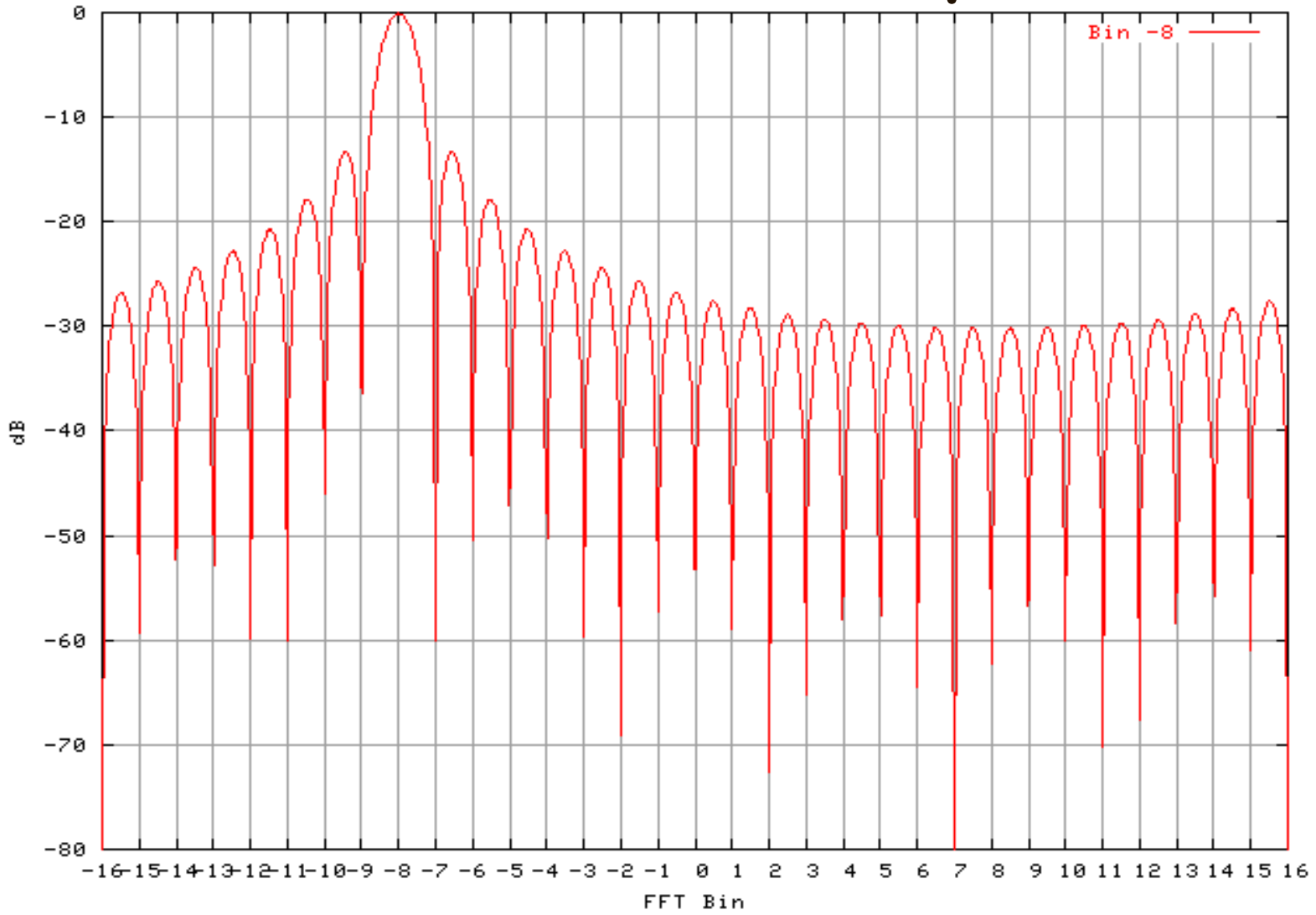
Here is Arecibo's "GALFA" down converter/PFB spectrometer

with (2 polarizations) * (7 antenna beams) = 14 PFBs.
Each PFB can make 7 MHz/8k = 8192 channels, each with 875 Hz BW
or 100 MHz/512 = 512 channels, each with 195 kHz BW



http://seti.berkeley.edu/galfa/

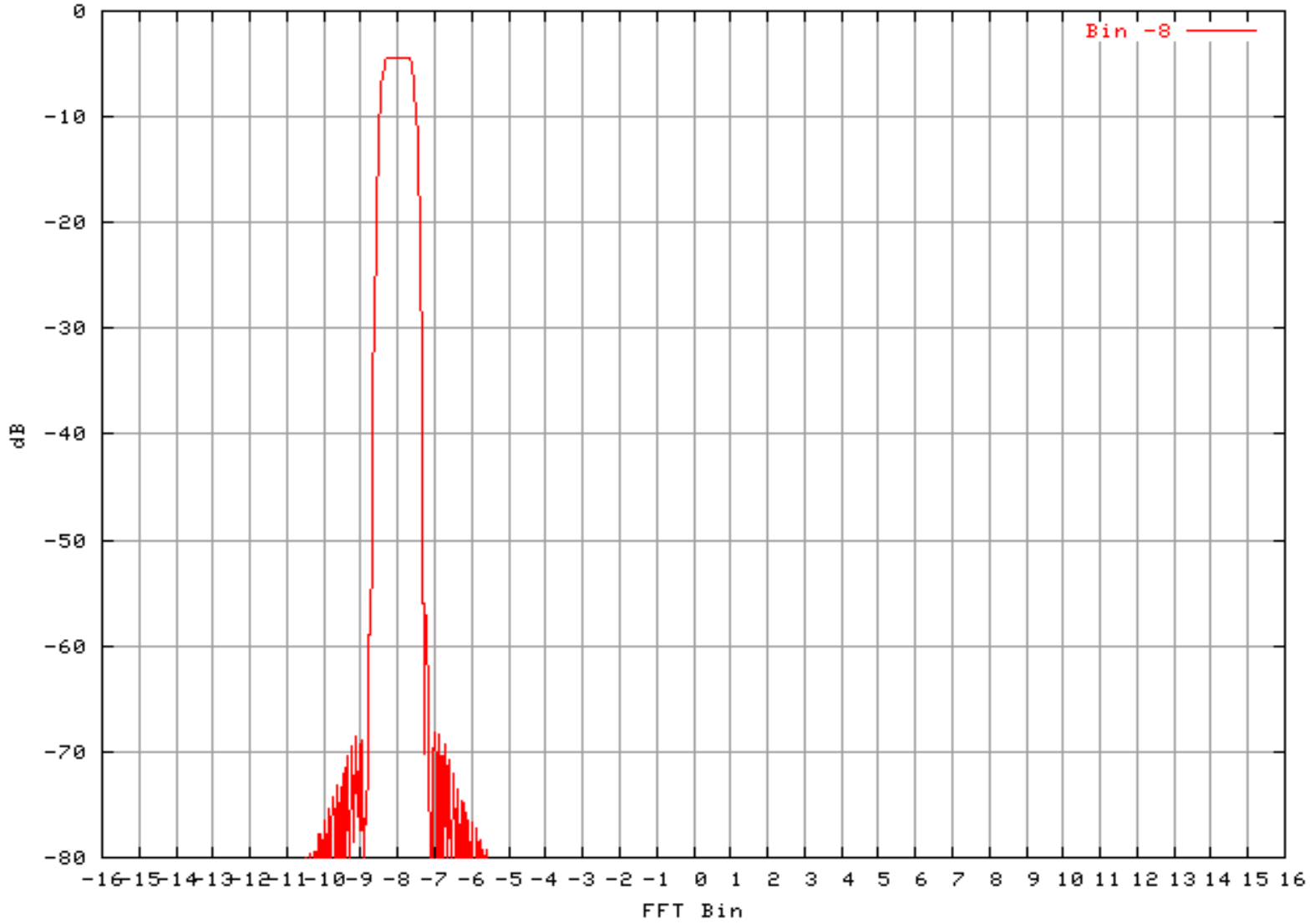
If a non-windowed FFT were to be used instead of the GALFA receiver @ Arecibo, each channel would have a $[\sin(x)/x]^2$ response like this:



Note the poor out-of-band rejection (-13dB in the first band outside the main lobe)

http://seti.berkeley.edu/galfa/signalproc/pfb.html

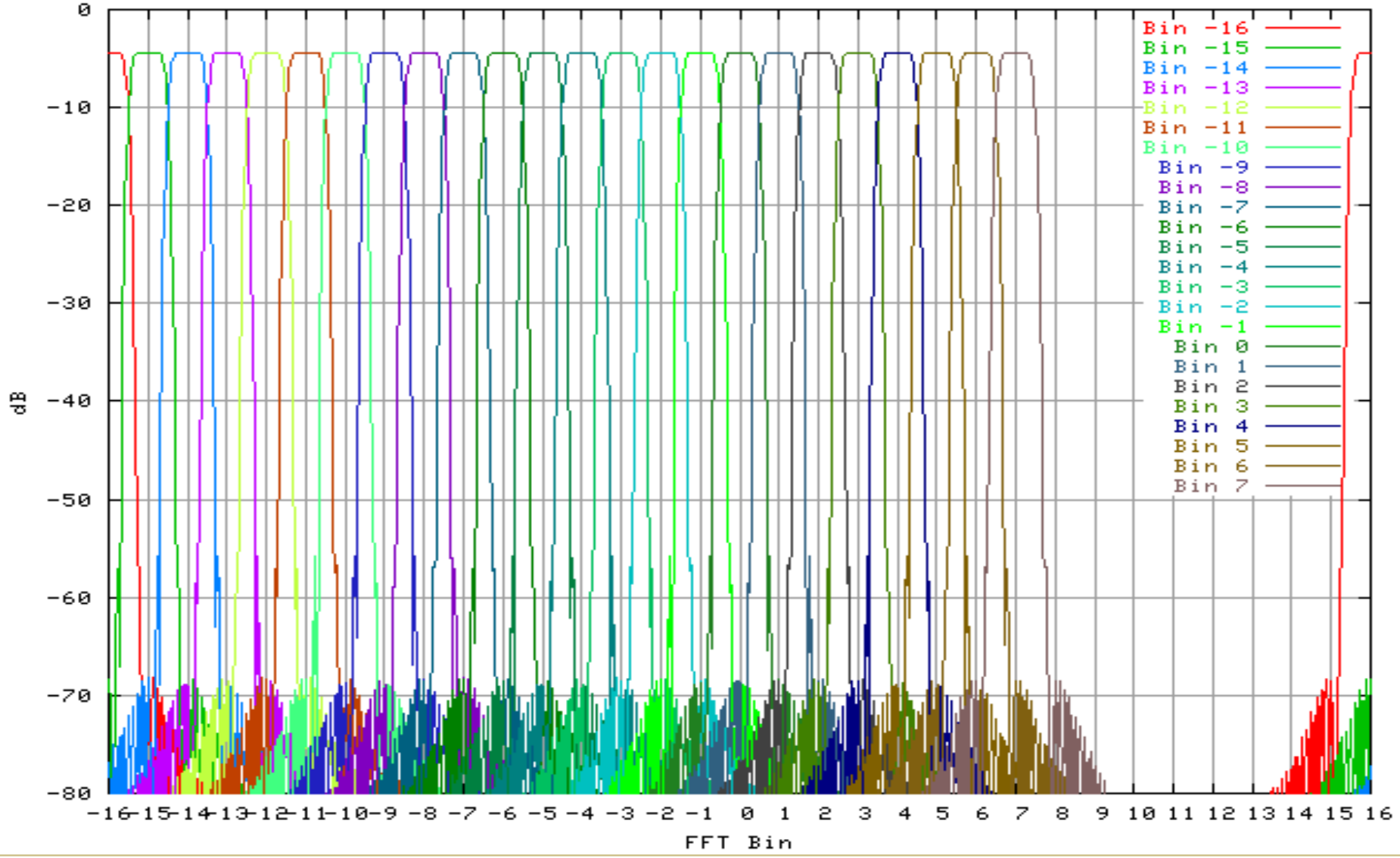
Frequency response of single PFB spectral bin (channel) in Arecibo's GALFA spectrometer.



Note that the largest out-of-band channel is about -68 dB, about 55dB better than the non-windowed FFT.

http://seti.berkeley.edu/galfa/signalproc/pfb.html

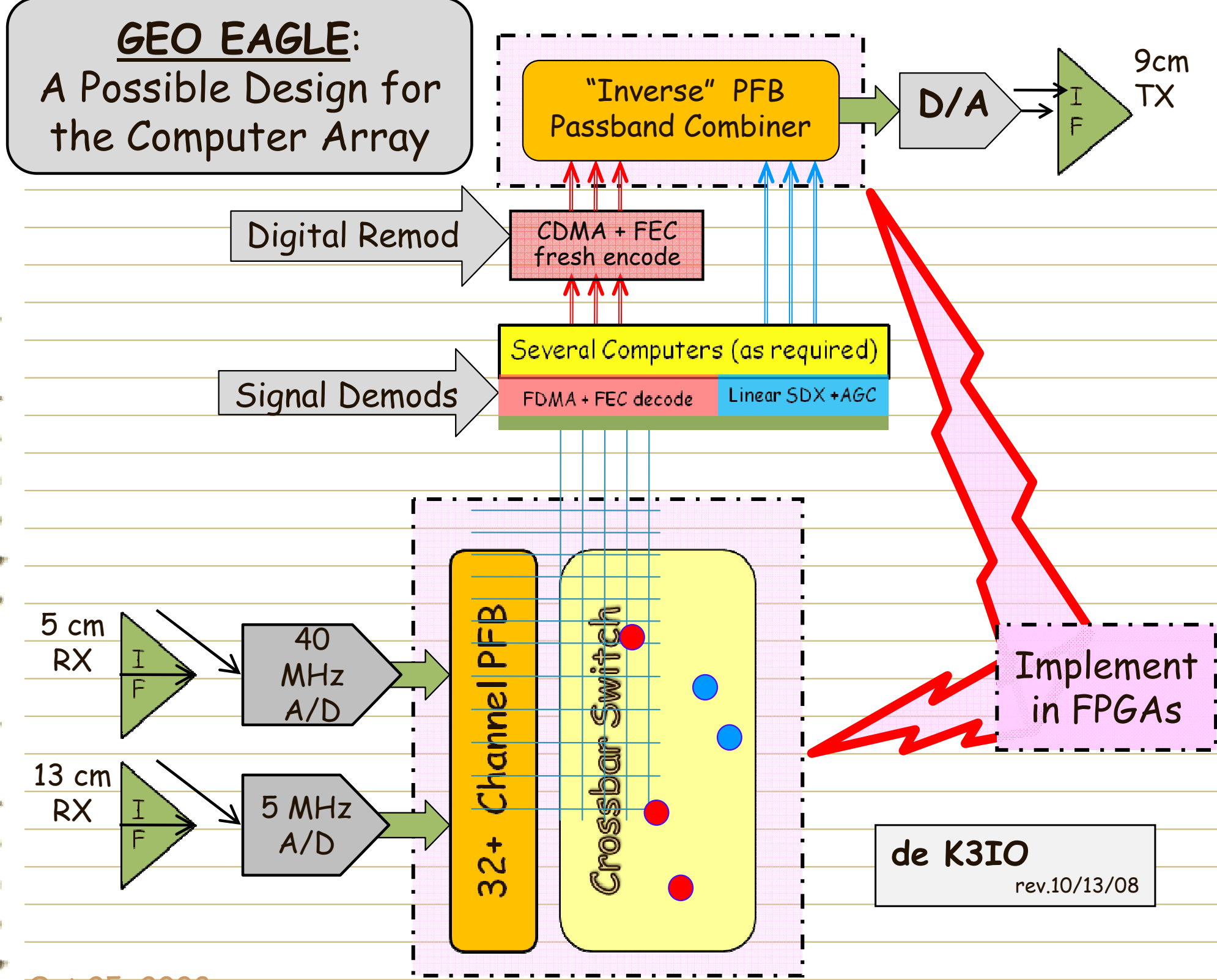
Arecibo's 32 channel GALFA Spectrometer is a PFB with 32 parallel digital channels.



The PFB is implemented in Xilinx (reprogrammable) FPGAs

http://seti.berkeley.edu/galfa/signalproc/pfb.html

GEO EAGLE:
A Possible Design for the Computer Array



Antennas: You will want to use a TV dish about 1 Meter in diameter at your QTH:

Freq, GHz	λ, cm	1M dish diameter, λ	Typical Gain, dBi	Beamwidth Degrees (FWHM)	Pointing Accuracy, Degrees
1.26 (L)	23.8	4.2 ☼	16.4	33.3	6.7
2.4 (S1)	12.5	8	22.0	17.5	3.5
3.4 (S2)	8.8	11	25.0	12.3	2.5
5.7 (C)	5.3	19	29.5	7.4	1.5
10.4 (X)	2.9	35	34.7	4.0	0.8
24.0 (K)	1.3	80	42.0	1.7	0.3
12.0 (Ku TV)	2.5	40	36.0	3.5	0.7

☼ Caution: Dishes should not be smaller than ~8-10 λ

These small dishes are so cheap that it makes a of sense to use separate antennas for TX & RX

Here's a pair of 60cm dishes bolted to a picnic table. These antennas are mounted on a computer controlled az-el pointing fixture and are used as a solar radiotelescope.

Figure 3. Front view of pair of dishes acting as a short baseline interferometer.

Folks with serious CC&R antenna limitations can use "stealthy" fixed small dishes that look like "legal" TVRO installations. ☺ ☺

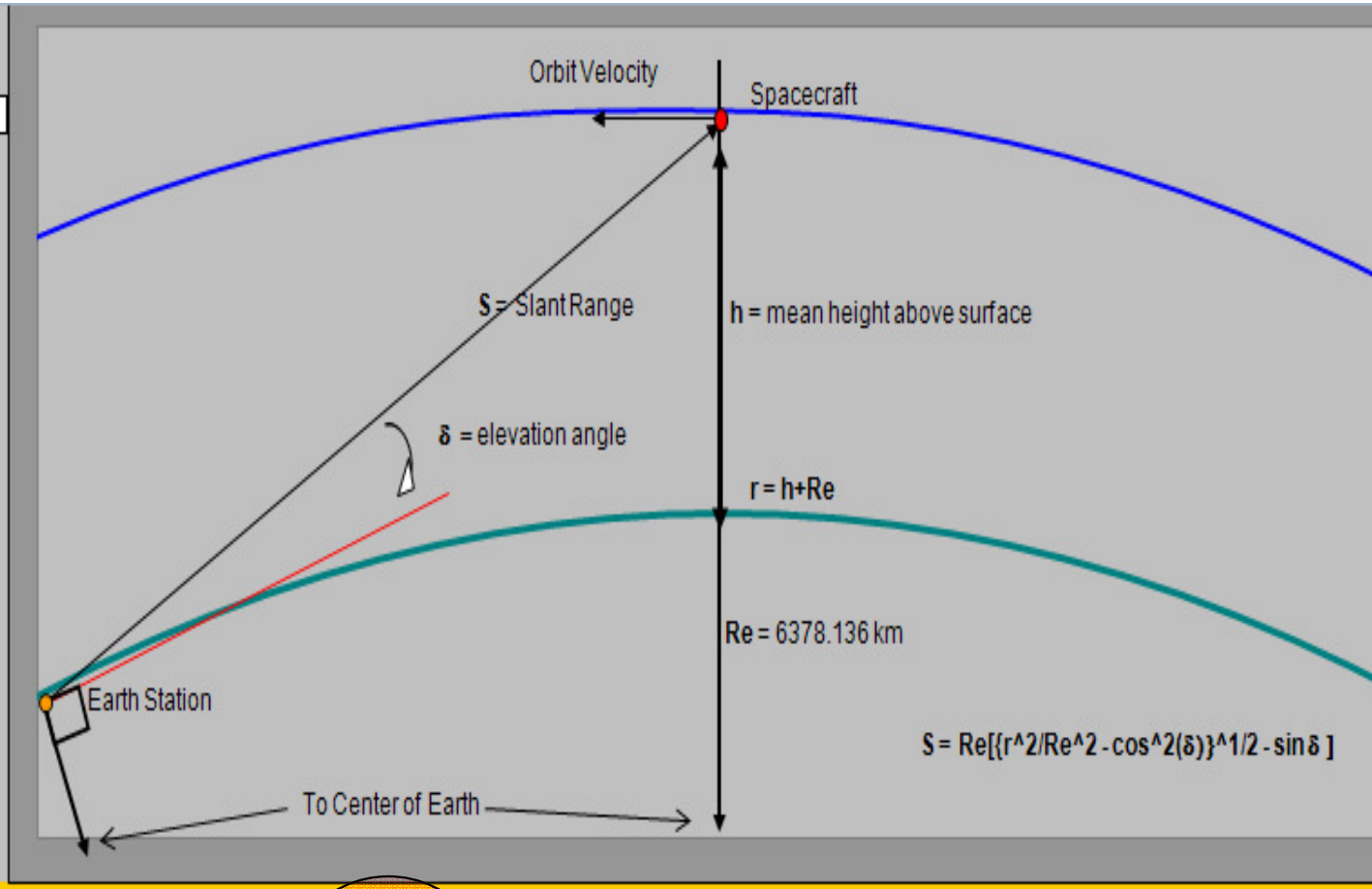
For details on using Ku-band dishes as a low-cost Radio Telescope, see http://www.haystack.mit.edu/edu/undergrad/VSRT/VSRT_Memos/009.pdf

Using W3GEY's Link Budget Tools: (1) Defining the Orbit

Orbit Properties

Slant Range to Spacecraft vs. Elevation Angle

Parameter:	Value:	Unit:
Earth Radius:	6,378.17	km
Height of Apogee (ha):	35,850	km
Height of Perigee (hp):	35850	km
Semi-Major Axis (a):	42,228.17	km
Eccentricity (e):	0.000000	
Inclination (I):	0.00	degrees
Argument of Perigee (ω):	0.0	degrees
R.A.A.N. (Ω):	7.00000	degrees
Mean Anomaly (M):	0.00	degrees
Period:	1439.331	minutes
dω/dt:	0.0267	deg./day
dΩ/dt:	-0.0133	deg./day
dM/dt:	Not Implemented	deg./day
Mean Orbit Altitude:	35850.00	km
Mean Orbit Radius:	42,228.17	km
Sun Synchronous Inclination:	0	degrees
Elevation Angle (δ):	0.0	degrees
Slant Range (S):	41,743.71	km.



	Frequency:		Wavelength (λ):	Path Loss:
Uplink:	5660	MHz	0.05297 meters	199.9 dB
Downlink:	3405	MHz	0.08805 meters	195.5 dB

Path Loss = 22.0 + 20 log (S/λ)

Using W3GEY's Link Budget Tools: Digital Downlink Estimates (2)

Intelsat Hitchhiker — Tom Clark, K3IO — Date Data Last Modified:

Downlink Telemetry Budget: — Version: 1.0 — October 21, 2008

Parameter:	Value:	Units:	Comments:
Spacecraft:			
Spacecraft Transmitter Power Output:	25.0	watts	
In dBW:	14.0	dBW	
In dBm:	44.0	dBm	
Spacecraft Transmission Line Losses:	-1.0	dB	
S/C Connector, Filter or In-Line Switch Losses:	0.0	dB	
Spacecraft Antenna Gain:	20.0	dBiC	
Spacecraft EIRP:	33.0	dBW	Spacecraft Effective Isotropic Radiated Power (EIRP) [EIRP=Pt x Ltl x Ga]
Downlink Path:			
Spacecraft Antenna Pointing Loss:	-0.5	dB	
Antenna Polarization Loss:	-0.5	dB	
Path Loss:	-195.5	dB	
Atmospheric Loss:	-1	dB	Use Value Appropriate for Elevation Angle Selected in Orbit Performance W/S. See Ippolito.
Ionospheric Loss:	0.0	dB	
Rain Loss:	0.0	dB	
Isotropic Signal Level at Ground Station:	-164.5	dBW	
Ground Station:			
------- Eb/No Method -------			
Ground Station Antenna Pointing Loss:	0.0	dB	
Ground Station Antenna Gain:	25	dBiL	
Ground Station Transmission Line Losses:	0.5	dB	
Ground Station LNA Noise Temperature:	50	K	
Ground Station Transmission Line Temp.:	290	K	
Ground Station Sky Temperature:	10	K	
G.S. Transmission Line Coefficient:	1.1220		
Ground Station Effective Noise Temperature:	26	K	
Ground Station Figure of Merrit (G/T):	11.4	dB/K	
G.S. Signal-to-Noise Power Density (S/No):	75.4	dBHz	Boltzman's Constant: -228.6 dBW/K/Hz
System Desired Data Rate:	100000	bps	
In dBHz:	50.0	dBHz	
Telemetry System Eb/No:	25.4	dB	Assumes Spectral Efficiency of 1.0 b.p.s./Hz of Bandwidth
Telemetry System Required Bit Error Rate:	1.00E-06		Assume G3RUH FSK; No Coding; 1 dB Implementation Loss
Telemetry System Required Eb/No:	18	dB	This Eb/No Required to meet B.E.R.
System Link Margin:	7.4	dB	

Ground Station Alternative Signal Analysis Method (SNR Compu		
---------- SNR Method ----------		
Ground Station Antenna Pointing Loss:	0.0	dB
Ground Station Antenna Gain:	25.0	dBiC
Ground Station Transmission Line Losses:	0.5	dB
Ground Station LNA Noise Temperature:	50	K
Ground Station Transmission Line Temp.:	290	K
Ground Station Sky Temperature:	10	K
G.S. Transmission Line Coefficient:	1.1220	
Ground Station Effective Noise Temperature:	26	K
Ground Station Figure of Merrit (G/T):	11.4	dB/K
Signal Power at Ground Station LNA Input:	-139.0	dBW
Ground Station Receiver Bandwidth:	64,000	Hz
G.S. Receiver Noise Power (Pn = kTB)	-166.4	dBW
Signal-to-Noise Power Ratio at G.S. Rcvr:	27.4	dB
System Desired Data Rate:	100000	bps
	50.0	dBHz
Telemetry System Required SNR:	18	dB
System Link Margin:	9.4	dB

Using W3GEY's Link Budget Tools: (3)
Digital Uplink Estimates

Intelsat Hitchhiker
Uplink Command Budget:

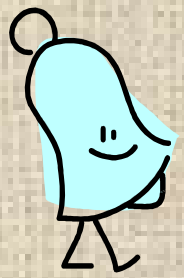
Tom Clark, K3IO
Version: 1.0

Date Data Last Modified:
October 21, 2008

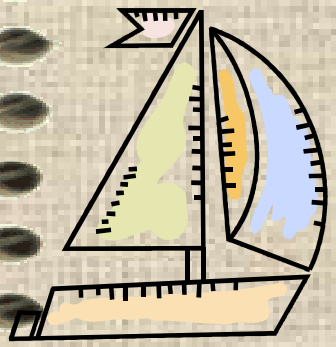
Parameter:	Value:	Units:	Comments:
Ground Station:			
Transmitter Power Output:	10.0	watts	
In dBW:	10.0	dBW	
In dBm:	40.0	dBm	
Transmission Line Losses:	0.5	dB	
Connector, Filter or In-Line Switch Losses:	0.0	dB	
Antenna Gain:	29.5	dBiL	
Ground Station EIRP:	40.0	dBW	Ground Station Effective Isotropic Radiated Power (EIRP) [EIRP=Pt x Ltl x Ga]
Uplink Path:			
Ground Station Antenna Pointing Loss:	-0.5	dB	
Antenna Polarization Losses:	-0.5	dB	
Path Loss:	-199.9	dB	
Atmospheric Losses:	1.0	dB	Use Value Appropriate for Elevation Angle Selected in Orbit Performance W/S. See Ippolito.
Ionospheric Losses:	0.0	dB	
Rain Losses:	0.0	dB	
Isotropic Signal Level at Ground Station:	-159.9	dBW	
Spacecraft:			
------- *Eb/No Method* -------			
Spacecraft Antenna Pointing Loss:	-0.5	dB	
Spacecraft Antenna Gain:	20.0	dBiC	
Spacecraft Transmission Line Losses:	-0.3	dB	
Spacecraft LNA Noise Temperature:	80	K	
Spacecraft Transmission Line Temp.:	270	K	
Spacecraft Sky Temperature:	20	K	+RFI ???
S/C Transmission Line Coefficient:	0.9333		
Spacecraft Effective Noise Temperature:	117	K	
Spacecraft Figure of Merrit (G/T):	-1.0	dB/K	
S/C Signal-to-Noise Power Density (S/No):	67.2	dBHz	Boltzman's Constant: -228.6 dBW/K/Hz
System Desired Data Rate:	10000	bps	
In dBHz:	40.0	dBHz	
Telemetry System Eb/No:	27.2	dB	Assumes Spectral Efficiency of 1.0 b.p.s./Hz of Bandwidth
Telemetry System Required Bit Error Rate:	1.00E-06		Assume Non-Coherent FSK; No Coding; 1 dB Implementation Loss
Telemetry System Required Eb/No:	17.0	dB	This Eb/No Required to meet B.E.R.
System Link Margin:	10.2	dB	

Spacecraft Alternative Signal Analysis Method (SNR Com	
---------- *SNR Method* ----------	
Spacecraft Antenna Pointing Loss:	-0.5
Spacecraft Antenna Gain:	20.0
Spacecraft Transmission Line Losses:	-0.3
Spacecraft LNA Noise Temperature:	80
Spacecraft Transmission Line Temp.:	270
Spacecraft Sky Temperature:	20
S/C Transmission Line Coefficient:	0.9333
Spacecraft Effective Noise Temperature:	117
Spacecraft Figure of Merrit (G/T):	-1.0
Signal Power at Spacecraft LNA Input:	-140.7
Spacecraft Receiver Bandwidth:	64,000
G.S. Receiver Noise Power (Pn = kTB)	-159.9
Signal-to-Noise Power Ratio at S/C Rcvr:	19.1
System Desired Data Rate:	10000
	40.0
Telemetry System Required SNR:	17.0
System Link Margin:	2.1

OK – That's the skeleton idea <u>for my GEO EAGLE concept</u>.



Does it ring your chime?



Does it float your boat?

Let me know

73 de Tom Clark, K3IO

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